

SOME NOTES ON THE FLORA AND FAUNA OF
MAMMOTH CAVE, KY.¹

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In 1889 there was published by the general government Dr. A. S. Packard's "Cave Fauna of North America, with Remarks on the Anatomy of the Brain and the Origin of the Blind Species," which constitutes the most complete treatise on cave animals which has appeared in this country. In that work there were listed eight genera and nine species of Infusoria, three genera and species of Vermes, four genera and species of Crustacea, eight genera and species of Arachnida, one of Myriopoda, twelve genera and fourteen species of Insecta, and two genera and species of fishes, all from Mammoth Cave. Dr. Packard also adds a list of seventeen forms said to be living temporarily in the cavern, most of which are listed on the authority of others. Of these one, *Spelerpes* or cave salamander, is listed on the uncertain authority of one of the guides. Excluding this list of seventeen, which includes three forms of *Helix* which most certainly came in from without, after death, and in floatwood, there remains a total of forty-one species. Seven of these are uncertain either in their generic or specific relations, as appears from the mark of doubt which is added to them. Of many of the forms concerning which there is no manner of doubt there are excellent descriptions and figures.

It is not my present purpose to speak of the forms which were known from Mammoth Cave prior to my own period of study, except in the most incidental manner. On the contrary, it is designed only to speak on the additions which more careful investigation has brought to light.

In the study of this new material the writer has been assisted by the following gentlemen, whose names are mentioned both that the fullest credit may be given them and that their high authority may attach to the determinations of the several forms

¹ Read before Indiana Academy of Science, December 30, 1896.

as being new. For the *Diptera*, Mr. D. W. Coquillett, of the Department of Agriculture, Washington; for the *Acarinæ*, *Thysanuræ*, *Therididæ* and related forms, Mr. Nathan Banks, of Sea Cliff, New York; for the microscopic plants, Dr. Roland Thaxter, of Harvard University. It is quite sure, therefore, that the determinations in these groups are quite accurate and authentic. For the single mollusk and the larger fungi the writer is alone responsible.

The conditions under which collections are made in Mammoth Cave are not of the simplest character. The cavern itself is very great, and the forms of life neither large, as a rule, nor abundant. Hours may be spent by a novice without any success attending his efforts, and it is only after much search and repeated failures that he begins to realize that the distribution of life within the cave obeys certain laws. Animals are not found everywhere; nor are they found in association, except in a few instances. Visitors frequently spend hours in the cavern and fail to see any evidence of life; but one who is somewhat familiar with the habits of insects soon discovers that the same principles which govern their distribution in the realms of light prevail in the subterranean world. In a short time one soon learns where not to look for life, a fact of as great importance to one whose time is limited as to know where to look. The darkness is inconceivably great, and hangs like a great burden on one who seeks the smaller forms. The crude methods of illumination avail to lighten but a small area at a time, and most of the forms appear to be sensitive to light while not possessing organs of vision; such, at least, is my conclusion after some years of collecting, though, it is true that the heat of the lamps may be the prime cause of the haste which many species evince when disturbed. From my experience in Mammoth Cave I have learned that it is practically useless to hunt for insects where the cave is very dry; regions of wet soil or sides are the most favorable localities for all the insecta. The smaller rills and springs in the cave usually contain an abundance of small crustaceans, but mainly of two forms; aside from these but one form of life is common in the water, or fairly so,

and that is the small white leech. An undetermined nematode worm, two specimens in all, has been found by the writer in a small rill which furnishes the water to Richardson's Spring, in the Labyrinth. On the walls about such places the "cave crickets" abound, and under the flat stones along the way may be found the very small and white spiders, associated with the small white and delicate *Campodea cookei*. Occasionally a brownish beetle, *Anophthalmus*, scurries across the over-turned stone, or may be seen running rapidly over the moist sands. In a few localities, where decaying toadstools are found, or where decaying vegetation of other sorts occurs, small flies occasionally appear fluttering in uncertain way about the lamps or run rapidly over the wet sand. In a single locality appears the minute mollusk, which we herein describe, the only known form which is a true cave mollusk in this cavern.

To the list of cave animals which appears in Packard's monograph must now be added seven forms, which are new to science, and several forms which, while known, have not before been definitely reported from Mammoth Cave. Without exception the new forms are very minute, and this fact is in itself sufficient to explain their late appearance in lists of the cave fauna. Without attempt to arrange them into strict systematic groups it will be enough to say that there is one new mollusk, one new dipterous insect, two new thysanurids, one new psocid, one new pseudoscorpionid, two new acaridids, among the animals; while several others have been collected in sufficiently great numbers to settle doubts connected with their affinities, or to make absolutely certain previous doubtful records or their occurrence. This is true of the two dipterous forms hitherto listed as *Sciara* and *Phora*, without specific names.

The descriptions which follow are prepared from the material collected by me by the gentlemen whose names are appended to the several forms, and the species are to be quoted with their names in authorship. This paper for the first time presents these new forms to science; their authors should have the fullest credit in citations. These new forms may be described as follows:

THYSANURA.

"*Entomobrya cavicola* Banks. Nov. sp. (Plate X, Fig. 2.)

"Length 2 mm. Whitish hyaline, intestine showing through darker; clothed with rather long scattered bristles and finer, shorter hairs; head not broader at tip in side view; no eyes; antennæ one-third longer than the head, first joint very short, second twice as long, third shorter, fourth longest; legs short, two claws at tips; mesothorax no longer than metathorax; first abdominal segment indistinct, fourth longer than third or second, fifth apparently entire, blunt at tip; furcula rather slender, mucrones curved. Several specimens. Mammoth Cave, Kentucky." (Banks.)

This minute species occurs in very great numbers in a single locality, a side avenue which leads over the narrow passage called the Labyrinth to the top of Gorin's Dome, in the older portion of the cave. In collecting it I had to lie on my face with the lamp close to the ground, and on turning over a fragment of an old wheel-barrow, that had been in the cave for two score or more years, and was so rotten that slight effort only was needed to tear it to bits, these little insects would be seen running about in every possible direction and in great haste. They were both on the under surface of the fragments of wood and also on the earth under them in equal numbers; when disturbed in the attempt to secure them the characteristic jumping movement of the group availed here to make collection difficult. It was noticed that many of them in springing up in the air would rise to an extraordinary height for so small an insect, frequently two or even three inches from the board. Others would land in nearly the same place as that from which they started, having a kind of boomerang movement that was, at least, curious. A paper bag would have secured hundreds by taking stick and all; but, as is usual on such occasions, the paper bag was not at hand. It is interesting to note, that while they represented a generation that must have been a long way from their beginning in the cave, introduced, of course, from the outside world originally, they still retained the habits of their earlier ancestors and of the group, and sought, in the

densest darkness, the security of the under surface of their shelters. It would seem that this habit, which is quite general for all the cave species observed by me, would be a strong argument in direct proof of the outside origin of the fauna as a whole. While many generations have passed these forms hide in the regions of perpetual darkness as completely and systematically as do their cousins and nearer relatives of the surface. It is further interesting to note that this species is eyeless, a fact to which Mr. Banks calls attention in his description.

“*Smynthurus mammothia* Banks. Nov. sp. (Plate X, Fig. 1.)

“Length 1 mm. White hyaline. Eyes distinct; antennæ have the first joint very short; second twice as long; third equal to second; fourth much longer, divided into five parts, the basal one long, the following three short, subequal, and a longer, slender one at tip; all, except the last joint, with hairs at tip. Legs are moderately long, two claws at the tip, each with a tooth above, the outer claw as long as the width of the tibia. There is a small tooth below on the dentes before the tip, and a larger one on the outside at tip over the insertion of the mucrones; the latter are shorter than the dentes, finely serrate below and with curved tip. Quite a number of short hairs on the posterior half of the abdomen, and on the anal tubercle. Three specimens, Mammoth Cave, Kentucky.” (Banks.)

Of these specimens one was found in association with the form described above, while two were found under damp stones near Richardson's Spring, in the Labyrinth. The form moves slowly about, under the influence of the heat from the lamps, but springs very like the *Entomobrya* when the attempt is made to take it. The white color alone enables one to detect it during its slow crawling movements; a considerable number escaped before they could be seized, dirt and all, by the forceps. I judge the species to be fairly common, since one of my notebooks records the form as occurring in some numbers as follows: “Small mite-like forms abundant under sticks near Richardson's Spring; with them are rare examples of *Anthrobia mammothia* Telkpf.” Mr. Banks' figures are very character-

istic, and well illustrate the hairy character of the animal. It has only occurred to me in this single locality, but may be found at other places in the cave where there are similar conditions of moisture.

PSOCIDÆ.

"*Dorypteryx* (?) *hageni* Banks. Nov. sp. (Plate X, Fig. 4.)

"Length 1.5 mm. Wholly pale, except reddish-brown eyes and mandibles. Head, thorax, legs and hind segments of abdomen clothed with fine short hairs. Ocelli sometimes distinct, sometimes not; basal part of antennæ of three joints, rest missing; maxillæ plainly trifid; legs slender, tibiæ much longer than femora, tarsi three-jointed, basal joint longest; wings rudimentary; second segment of the abdomen very long and smooth, subcylindric, forming the greater part of abdomen, on the venter it is prolonged by a median triangular piece over the next segment; other segments much shorter, and tapering to the tip.

"Several nymphs from Mammoth Cave, Ky. This may be the species to which Hagen refers in Packard's Cave Memoir, but it certainly is not the *Dorypteryx pallida* Aaron, which differs in broader nasus, more prominent eyes and larger thorax." (Banks.)

A number of specimens were found under wet and decaying fragments of boards in the Labyrinth in a small pit under the way leading to the top of Gorin's Dome. In this locality are the accumulations of many years of replacement of old bridges and steps which lead up the steep declivity which is so near the Dome, and the debris, well decayed and crumbling, affords the richest collecting ground in the cave. Spiders, flies, beetles, crickets, myriopods, mites all are here and the largest series to be found at any single place may be obtained. The particular forms which are the subject of this description find abundant food in the microscopic fungi which here abound.

ACARINA.

"*Rhagidia cavicola* Banks. Nov. sp. (Plate X, Fig. 3.)

"Length .7 mm. Whitish, legs hyaline. Cephalothorax pointed behind, and with a distinct segment behind it and be-

fore the abdomen, cephalothorax plainly longer than broad, truncate in front, no eyes; the abdomen rather narrow at base, broadest toward the middle and broadly rounded at the tip, showing above faint transverse marks or sutures; legs rather stout, with scattered bristles; mandibles large, chelate, a little shorter than cephalothorax, directed slightly downwards; palpi a little longer than the mandibles, second joint three times as long as broad, third fully twice as long as broad, and with two bristles at the tip, fourth about as long as broad, with five or six bristles at the tip arranged in a somewhat radiate fashion.

“Several specimens, Mammoth Cave, Kentucky.” (Banks.)

This mite is a somewhat common species, and is found on the under side of stones in damp stations; especially may it be found under stones on which the egg masses of the cave spider, *Anthrobia mammothia* Telkpf, occur. I do not know whether it attacks these masses in any way, but the association is suggestive of that conclusion. The species is one of the smallest of the living forms found in the cavern, being exceeded in that particular only by the following one. It has only occurred in collections from near the bottom of the Bottomless Pit and in Blacksnake Avenue, in which Richardson's Spring is located. More than two-thirds of all the species known from Mammoth Cave came from near this station or at it.

“*Linopodes mammothia* Banks. Nov. sp. (Plate X, Fig. 5.)

“Length .5 mm. Pale yellowish, legs paler. Body oblong, rounded in front and behind; cephalothorax as broad as long, a shining eye on each side distinct; abdomen globose, above a silvery T mark, dorsum with a few hairs above, longer ones at the tip, and small ones each side of anal opening; leg I very long and slender, femur I as long as body, tibia shorter, metatarsus much longer than body, tarsus shorter, apparently not divided, femur IV thickened; the mandibles form a rather elongate cone; palpi plainly longer, joints two and three and subequal, smallest at base and rather clavate in form, fourth smaller and shorter.

“Several specimens from Mammoth Cave, Kentucky.” (Banks.)

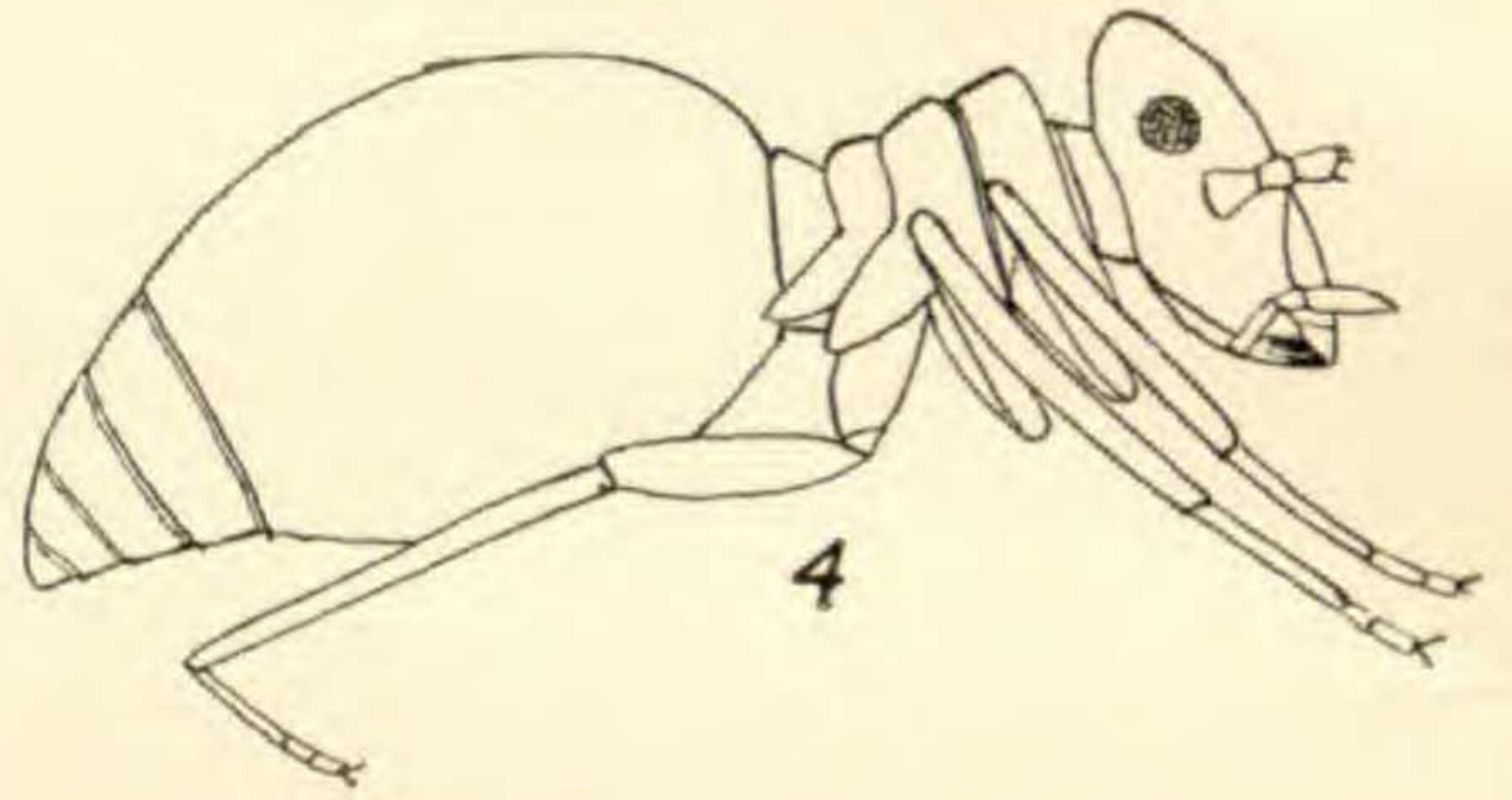
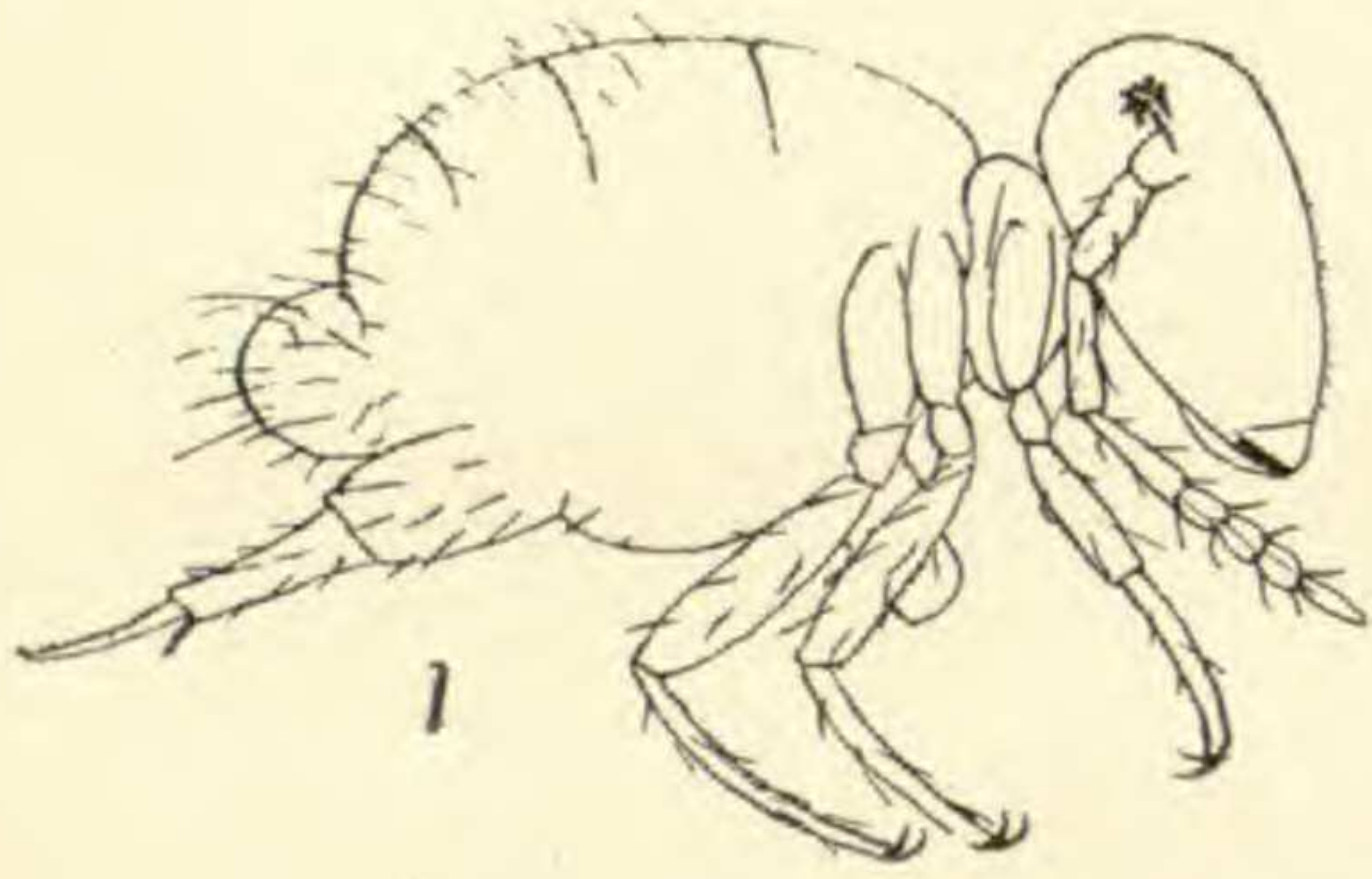
In all I have secured some fifteen specimens of this little acarid, which is the smallest form yet discovered in the cavern. It occurs on the under side of damp stones and sticks, in association with the thysanurids, which are described herein, and is easily distinguished in collecting. The very long first pair of legs give it a most peculiar aspect, and as they are always in somewhat rapid motion they serve to discover the little insect to the observer. Then, too, the species has the curious habit of raising itself up so that it stands on the first and fourth pair of legs when disturbed. It is exceedingly slow in its movements. Vision is impossible in the cave, notwithstanding its bright eyes, and possibly the bristles or hairs of the posterior abdomen, on dorsal surface, have a certain tentacular function—using the word in the sense of organ of touch. It may be said that the species was originally detected, and subsequently always found, by lying prone on the ground and with the lamp as close as possible to both face and soil. The heat appears to disturb the minute specks of pale yellowish color, and they appear to move; then dirt and all were collected and transferred to the alcohol vial, and the microscope eventually discovered the animal. At the first and several following trials it was a matter of serious question whether I had really seen anything move, so small are the objects. Like many another form the original discovery of this one was an accident.

DIPTERA.

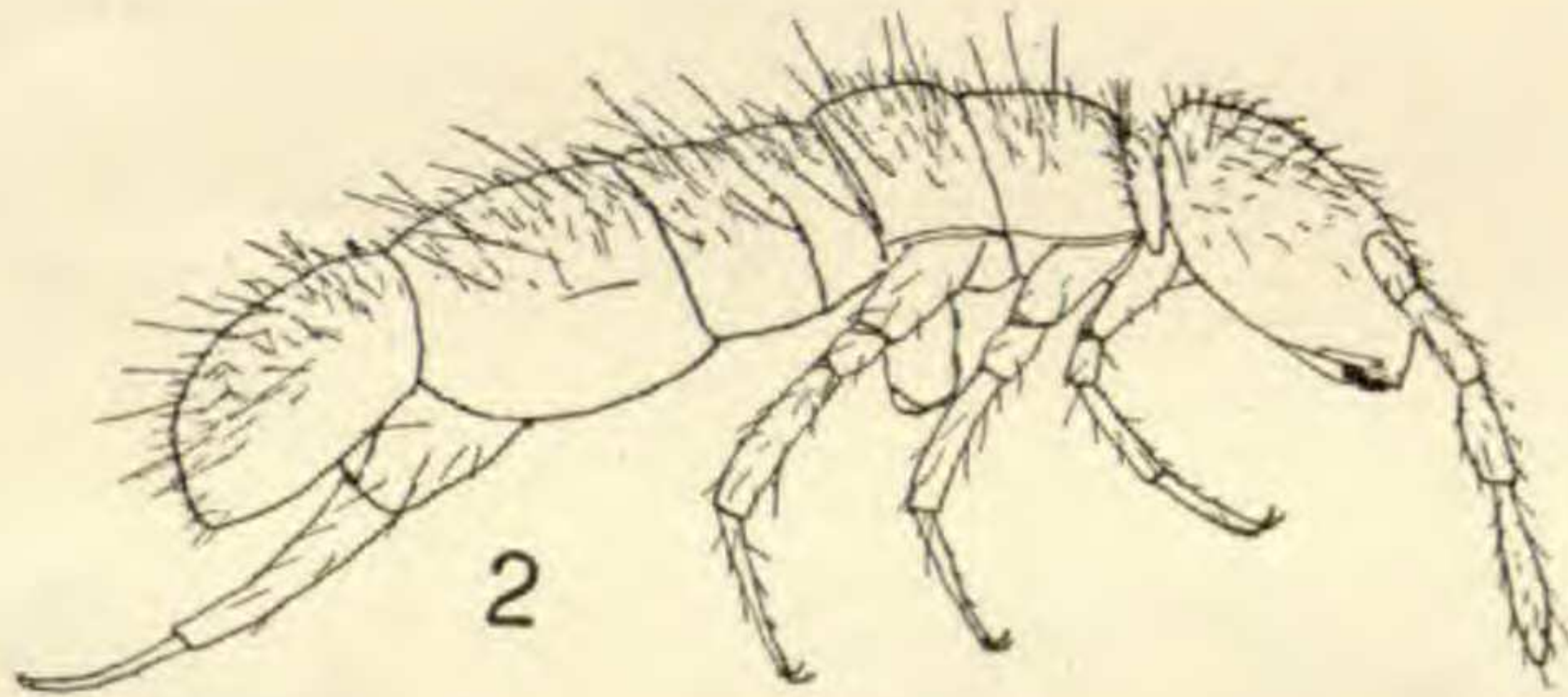
Limosina stygia Coquillett. Nov. sp.

“Male and female specimens. Black, subshining, the palpi, front coxæ, apices of femora and bases of the tibiæ (most extended on the front pair), also bases of the tarsi and of the halteres, yellowish. Middle tibiæ each bearing a bristle on the outer side above the middle, a pair at the apex on the outer side and a single one on the inner side at the tip; hind tibiæ destitute of a spur at the tips; first joint of hind tarsi one and one-half times as thick as, but only two-thirds as long as, the second, twice as long as broad; second joint one and one-half times as broad as, and one and one-third times as long as, the third; remaining joints slightly broader than but only two-

PLATE X.



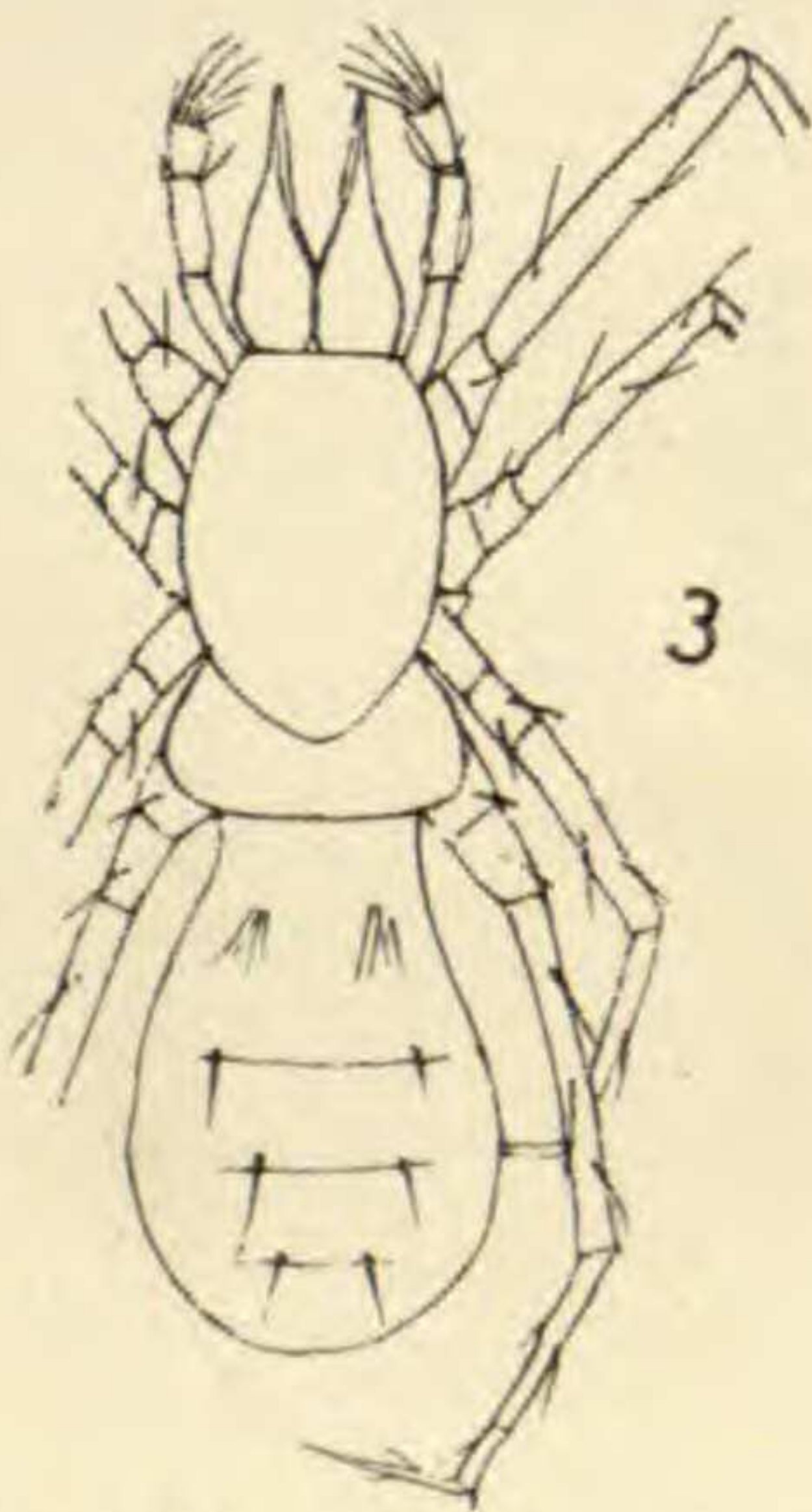
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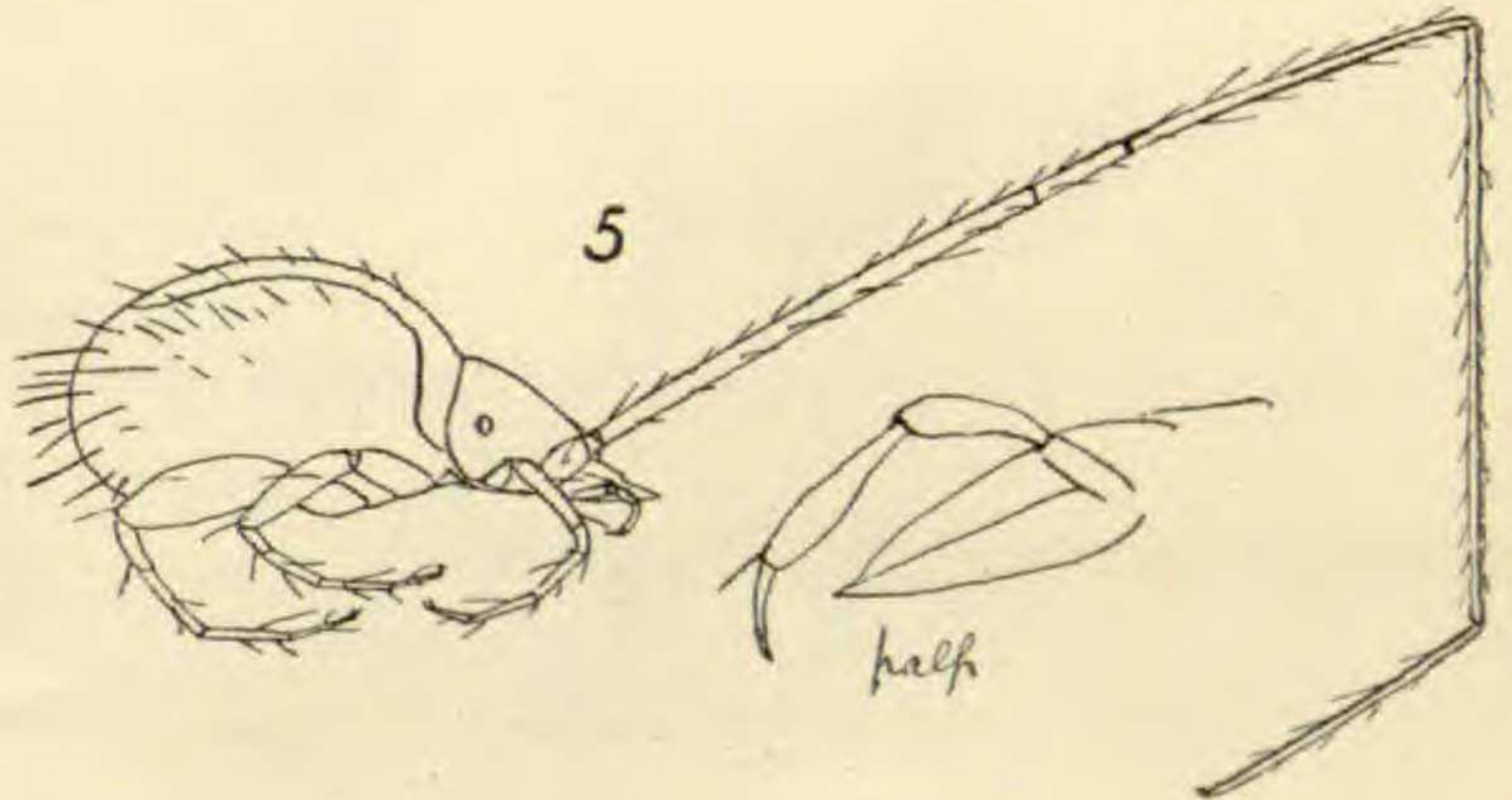
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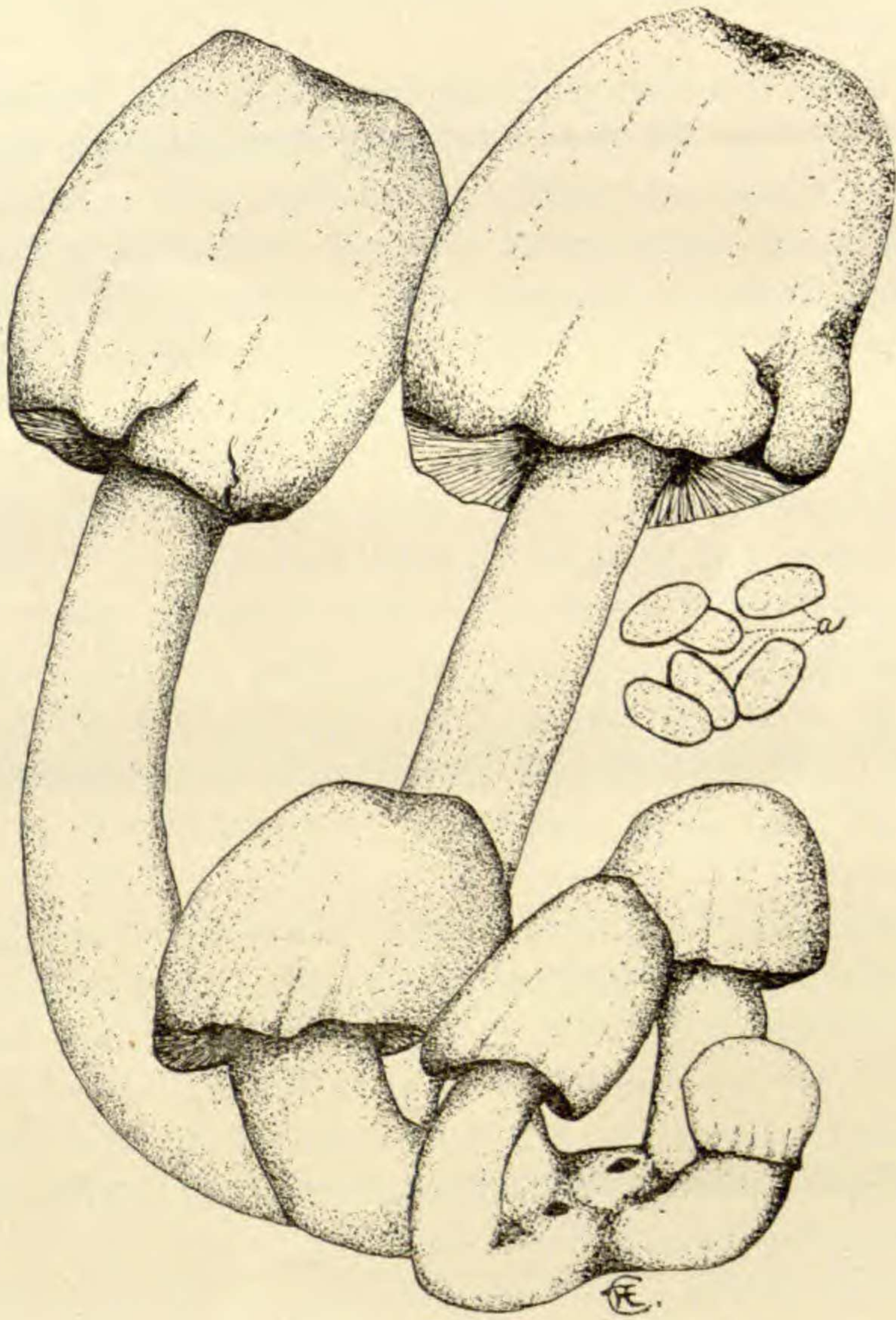


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half

Fig. 1. *Smynthurus mammothia* Banks. Fig. 2. *Entomobrya cavicola* Banks. Fig. 3. *Rhagidia cavicola* Banks. Fig. 4. *Dorypteryx* (?) *hageni* Banks. Fig. 5. *Linopodes mammothia* Banks. Figs. 6-7. *Carychium Stygium*.

PLATE XI.



Coprinus micaceus.

thirds as long as the third. Scutellum bare, except for the four marginal bristles. Wings grayish hyaline, tip of second vein nearly midway between the apices of the first and third veins, third vein nearly straight, terminating close to the extreme wing-tip, fourth vein subobsolete beyond the discal cell, fifth vein continued beyond the hind cross-vein over one-half of the length of the latter, second basal and anal cells wanting. Length 1.5 mm. to 3 mm. Fifteen specimens, collected in alcohol, from Mammoth Cave, Kentucky." (Coquillett.)

A considerable number of additional specimens have been secured since the original lot which was forwarded to Mr. Coquillett, representing both sexes. These specimens and the original ones all came from the same parts of the cave, in which the species is fairly common. The number of individuals appears to be quite considerable, and many more could have been secured with a good net and proper appliances. The localities are all in River Hall, one near the Cascade, which is to the right of the visitor who crosses the Styx; the other is near the head of Echo River. In both localities the floor of the cave is covered with a thick coating of rich mud, which contains enough dead organic matter to permit the rank growth of clumps of large hymenomycetous fungi of the genus *Coprinus*. In the decaying specimens of this fungus the flies are found, both in larval form and in imagos. They run about over the wet earth and clay rather briskly, or, if disturbed, fly a short distance and again settle down. The species is the smallest that is found in the cave. The body is, however, considerably heavier than that of the *Phora* which is herein described.

The two forms next following have been reported only by generic name from Mammoth Cave. The material collected by me was somewhat abundant, and definitely places these forms in the cave fauna. The original descriptions are given together with the bibliographic references; these are followed by a new description prepared by Mr. Coquillett, based upon the males, in the first case, and upon specimens of both sexes in the description herein newly made.

Sciara inconstans Fitch.²

² First and Second Reports on the Noxious, Beneficial and other Insects of the State of New York, p. 255, 1856.

“It measures 0.08 in length, and is black, with the thorax smooth and slightly shining, the thighs pale and whitish, and the wings pellucid and glassy, with an iridescent violet and red reflection.” (Fitch.)

This very brief and incomplete description, without access to the types, would hardly enable recognition of this form. To it may be added the following:

“Male. Brownish-black; bases of the halteres, coxæ, femora and tibiæ, yellow. Antennæ as long as the body. Each apical joint of the hypopygium bears a cluster of short spines on the apical third of the inner side. Wings grayish hyaline, strongly iridescent, veins brown, fourth vein more slender than the others, forking at a point beyond the tip of the first vein, equaling the greatest width of the marginal cell, the anterior fork as long as the preceding section of that vein; last section of the first vein about as long as the preceding section; costa gently convex on the basal half.

“Female. Same as the male, except that the antennæ are only half as long as the body. Last joint of the ovipositor nearly one-third longer than broad. Length 2 mm. to 4 mm.” (Coquillett.)

A number of specimens, over twenty in all, were obtained at several points in Mammoth Cave. One locality is in the small dome in the Labyrinth, near the Bottomless Pit; another, is the Mammoth Dome, in another part of the cavern; a third is at Richardson's Spring, in Black-snake Avenue; and another is at the bottom of Gorin's Dome. At Richardson's Spring was found an apple quite decayed in which hundreds of the larval forms of this species were found, and nearly a hundred secured. Careful search in suitable localities failed to disclose the puparium of this form. It appears to be quite abundant in the damper portions of the cavern.

Phora rufipes Meigen.³

(Translation.) “Black, halteres white, legs reddish-yellow, wings hyaline. It differs from the foregoing [*annulata* Meig.

³ Klassifikation und Beschreibung der europäischen zweiflügligen Insekten, p. 313, 1804. (Work not accessible.)

Systematische Beschreibung der bekannten europäischen zweiflügligen Insekten, pp. 216-217, 1830.

=*rufipes* Meig.] only in lacking the white sutures on the abdomen. The male has a nearly conical, long haired body. One line."

Mr. Coquillett has prepared the following description from my specimens:

"*Phora rufipes* Meigen. Male and female. Brownish-black, palpi, halteres and legs yellowish. The four lowest median frontal setæ directed downward. Legs destitute of bristles except a pair at tip of inner side of each middle tibia and a single bristle at tip of inner side of each hind tibia. Abdomen of the male covered with rather long and nearly erect bristles. Wings hyaline, costa from base to tip of second heavy vein fringed with rather long bristles, second heavy veins forked at the apex, first slender vein arcuate at the base, then nearly straight to the tip. Length 2 mm. to 3 mm." (Coquillett.)

This species appears to be less abundant than either of the other dipterous forms. It occurs in Mammoth Dome and in the Labyrinth, in association with the *Sciara inconstans*. It flies about more freely, and when disturbed does not again light near by. In the Mammoth Dome I found the species running about among the masses of *Rhizomorpha*, which are so abundant on very old and decayed timbers in that portion of the cave.

MOLLUSCA.

Carychium stygium. Nov. sp. (Plate X, Figs. 6-7.)

Shell minute, white, pellucid, shining; whorls 5 to 5.5 in number, convex above and rather flattened below, apical whorl blunt-rounded in most specimens, occasionally more acute; suture deeply impressed, quite regular; aperture a little less than one-fourth total length of the shell, rather sharply angular above and broadly rounded below, with its plane forming a very acute angle with axis of the shell; lip reflexed in mature specimens; many examples, but not all, with a sharp, white, and long denticle on the parietal wall near the junction of the upper portion of the apertural boundary; the spire is generally quite regularly and narrowly conical, but the body whorl is

somewhat turgid. The length of the shell is 1.5 mm. to 1.85 mm. The aperture is nearly as broad as long. (Call.)

About 150 examples of this minute mollusk were secured during various visits to Mammoth Dome, in Mammoth Cave. They were found on the wet surfaces of the old bridge timbers, in that portion of the cavern, which have remained undisturbed for fifty or more years. Growing on these in great tufts or masses, forming a shaggy mantle that enveloped the great timbers throughout their length, was a species of *Rhizomorpha*, a peculiarly modified and sterile form of basidiomycetous fungus; in the midst of this fungous growth occur numerous examples of this shell. Occasional specimens are found on the under surfaces of the wet rocks of this part of the cave, but none have ever been taken in a dry situation in the Dome. The constant dripping of water, which in the wet season is a stream falling from the roof 150 feet above, keeps the rocks and old timbers, with their fungous growths, all continually wet, and, except the utter darkness, makes the place a desirable home for "a well brought up" *Carychium*.

This species is much smaller in the relative size of the aperture and length of shell than its nearest ally *Carychium exiguum* Say. But it is a much heavier shell, far more rounded and shining than that form. *Carychium exiguum* from Indiana and New York, with which I have compared it, is a much slenderer shell. Compared with the doubtful *Carychium exile* Lea it has a broader body whorl, is more conical, and has no striations, which are marked features of that form. Compared with the so-called *Carychium occidentale* the shape and size of the body whorl are different, the form of the lip and the curvature of the outer lip above are distinct. Since our form seems to be constant in all these differences it has been decided to present it under the name of *Carychium stygium*. Specimens may be seen in the Academies of Natural Sciences of Philadelphia and Cincinnati, and in the United States National Museum. The types are in the Call Collection at the Indiana State University, Bloomington.

The remainder of the new forms are plants, and but a brief mention will be made of them. Several of the lower fungi

have been reported from Mammoth Cave, but most of them with doubt. Among the larger fungi Hovey has reported a species of *Agaricus*, which, however, seems to have been wrongly determined, since the form is a *Coprinus*. Collections were made at various localities; indeed, at all places in the cave where plant life occurs at all. While these have not all been carefully studied certain facts of interest have been gleaned. These now follow.

The largest form known in the cave is *Coprinus micaceus* (Plate XI). This occurs only in River Hall, near the Cascades and at various points between them and the head of Echo River. The last locality seems to be extremely well suited to them, for they grow in some numbers, and in clusters of several individuals. As is well known, the pileus of the *Coprini* is deliquescent. The particular form from the cave has black and rather large spores, and when, in maturity, the form deliquesces, it runs over a considerable area of the wet soil surrounding it and makes large black patches of sticky or gelatinous matter. In the midst of this black area, for some two or three days, the stipe will remain standing and afford attractive bits for *Adelops* and *Phora*, the first a beetle, the second a fly. In the pileus, before deliquescence is completed, the beetles and flies alike may be found in the burrows which the former have made. Many larvæ were obtained through a close examination of fifty or more specimens, at one time or another. The fungus itself thrives in the rich mud of the river banks, where sufficient organic matter is buried, and specimens have been seen with long and curled stipes of more than thirteen inches length. A locality where the species may always be found is at the third arch or landing on the Echo River, on the steep muddy banks of the river near the bridge.

On the old timbers in Mammoth Dome and on those of the little pit near Gorin's Dome, in the Labyrinth, occurred in great numbers a small *Peziza*, very light reddish-brown in color and thriving well, though growing in absolute darkness. In the Mammoth Dome the form must have long sustained itself, for it has been many years since timbers were placed there; unless, indeed, the spores were introduced in a very likely manner, on

the smaller tree timbers, which are used in the construction of the railings and walks along the Styx and the Dead Sea. These are taken into the cave by way of Little Bat Avenue, and Mammoth Dome, being let down from the top, and thence taken by Spark's Avenue to River Hall. Whether this be the real manner of spore introduction matters little; it is important to note that a form which almost commonly needs the light and warmth of sunshine to develop well here apparently thrives in absolute darkness and at a temperature which averages 54°.

In this same locality occurs the problematical form of basidiomycetous fungus, which is called *Rhizomorpha molinaris*?, living in the greatest profusion on the old sticks and timbers which here abound. Some specimens of beams that have remained in the lowest and wettest portion of the Mammoth Dome for many years are covered from one end to the other with the long root-like filaments of this plant. The greater number of the living filaments were of a deep brownish color, shading into a very light red tip, which became colorless at the extreme end. They appeared to be covered with a "bloom" which was lost after touching them. Opportunity to again examine them might disclose the phosphorescent phenomena for which these forms are celebrated in mines, a fact not known to me at the time of their original collection. The species occurs in no other part of the cave.

At numerous localities, where there is some moisture, occurring on dead specimens of *Hadencæcus subterranea*, the so-called "cave cricket," is *Isaria (Sporotrichum) densa* Link. This fungus is one of the most beautiful when growing in suitable stations, the mass appearing as a flocculent bunch of cotton clinging to the walls or lying on the damp earth. I have found the form in many localities, but most abundantly in El Ghor and along River Hall. Associated with it is the yellow form to which the name of *Isaria (Sporotrichum) flavissimum* Link has been given. But the yellowish form grows less luxuriantly and is found on other decaying matter, while the first named occurred to me only on dead *Hadencæcus*.

A number of moulds and other low forms have been collected by me at different times, and been studied by Dr. Thaxter, of